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Livelihood vulnerability assessment and climate change perception analysis in Arunachal Pradesh, India

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Abstract Climate change induced frequent disasters pose severe threats to agro-based rural livelihoods. Perceptions of risks play a critical role in planning and averting disasters. Lack of analytical documentation concerning how vulnerable communities perceive climate risks is a barrier to addressing and averting disasters and maladaptation. Applying a mixed approach, this study examines the perception of households concerning climate change and analyses the impacts of climate change on livelihood in Arunachal Pradesh, the largest northeastern state of India, with severe climate related challenges. Conceptual livelihood vulnerability index (LVI) framework of Intergovernmental Panel on Climate Change is adopted to analyse the climate change induced vulnerability on livelihood. A total 450 households from 18 villages located in the districts of Arunachal Pradesh were surveyed during October, 2021 for retrieving the ground complexities in the region. Decrease in yields, frequent landslides and floods, livestock losses and unpredictable weather condition were perceived by the sampled households. The LVI analysis indicated that households are vulnerable in Arzoo, Perum, Pekong and Amliang villages requiring priority for lessening livelihood vulnerability and increasing coping capacity of the communities. Correlation analysis indicated that climate variability, natural disaster, health, food and social components attributed to livelihood vulnerability in the study area. Alternate livelihood, enhancing preparedness to disasters, inclusion of women in workforce, sustainable livelihood practices and government assistance are some of the suggestions made to enhance the adaptation of local communities in a sustainable way.

Keywords Contributing factors · LVI · Household perception · Climate Change · Adaptation

Introduction

Climate change poses severe and uneven threats to many communities and human activities globally. Understanding of climate change components i.e., intensity, variability and frequency is essential for the recognition of various vulnerabilities associated with them. Increase in the intensity and frequency of climate related hazards with region specific implications (Rangel-Buitrago et al., 2020) meant adaptation is required to withstand the implications by vulnerable indigenous communities. The recent IPCC (2021) report reiterated that the adverse impacts of

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climate change and associated hazards would be on livelihoods, society, economy, health and well-being, infrastructure, cultural assets, ecosystems and its services. Furthermore, climate change may lead to alterations in the hydrological cycle causing unpredictable and intense rainfall in many areas. The severe implications will be on biodiversity, water resources and water flow regimes. These implications are enough to distress the populations relying directly on natural resources for the sustenance of their livelihoods (Koech et al., 2020). These changes are likely to severely affect the developing nations compared to those nations with better infrastructure and higher capacity to adapt and will take decades to attain resilience (Akanwa & Joe, 2019). Exponential increase in the population has aggravated the pressure on natural resources, food supplies and agricultural yield. It is also projected that water consumption for agriculture would increase greater than 19% by 2050 in case of no policy measure and suitable technological improvement (United Nations, 2012). Therefore, there is a need assess the livelihood vulnerabilities of agro-based communities and relate it to how they perceive the risks.

The negative implications of climate change are evident on the agricultural productivity (Mahmood et al., 2021). Changes induced by climate change in the rainfall and temperature patterns have significant influence on the crop yield. Food security is an important indicator of climate change induced household vulnerability as it includes the unemployment, loss of purchasing power and insufficiency of dietary needs (Shah et al., 2020). Livelihood in rural areas of developing nations is affected by climate change leading to the vulnerability of the rural farmers due to their dependence on ecological services (Mahmood et al., 2021; Shah et al., 2020). Sustainable development goal 2 (SDG 2) emphasises the need to promote sustainable agriculture for achieving food security and end huger by 2030 (Muringai et al., 2020). Despite the challenges posed by climate change, livelihood security is not adequately assessed leading to unsustainable practices that do not meet the requirements of farming community (Blackmore et al., 2021). Thus, the cognizance of climate change implications on livelihood and vulnerability of the communities is to execute effective planning and implementation of effective adaptative measures (Aribi & Sghaier, 2021).

Review of literature

Livelihood is multidimensional which reflects how people build their lives and adapt to overcome various threats to their wellbeing. Diversification of assets, improvement in infrastructure and activities and social support may help in augmenting livelihood and elevating the opportunities (Olsson et al., 2014). Livelihood is an integral part of climate change induced vulnerability and risk. Vulnerability assessments are critical in not only reflecting the susceptibility and risk of communities to climate change induced disasters, but also helpful in directing developmental interventions, strategies to uplift the livelihoods of the communities, facilitating measure to reduce risk and encouraging authorities to formulate effective policy measures (Cannon et al., 2003). Livelihood vulnerability indices (LVI) have been developed (for e.g., Hahn et al., 2009) by integrating multiple factors to examine the degree of vulnerability in specific regions and communities. Climate variability, natural disaster, socio-economic, health, food and water resources characteristics that regulate the sensitivity of the community in a changing climate are key factors used for livelihood vulnerability assessment (Hahn et al., 2009). The rural households in the developing nations are the most disturbed by the climatic shocks which pushes them towards poverty and food insecurity (Endalew & Sen, 2021). LVI is associated with various factors of socio-economic, livelihood practices and knowledge of climate change which helps in identifying how climate change is associated with the socio-economic factors (Aribi & Sghaier, 2021).

Numerous biophysical, economic and social factors including high population density, socio-economic inequalities, meagre infrastructure, poverty, etc. exacerbate the vulnerability. Social vulnerability depicts the interaction of biophysical factors with communities and thus, attributing the livelihood vulnerability (Das et al., 2020). Regional level vulnerability assessment is essential for understanding the complexities driven by climate change as the adaptive capacity of the communities depend on the financial, technological, cultural and institutional capabilities (Venus et al., 2022). Higher vulnerability can be identified in those areas where the impacts of environmental stressors are more. Several methods are being used to examine livelihood vulnerability, such

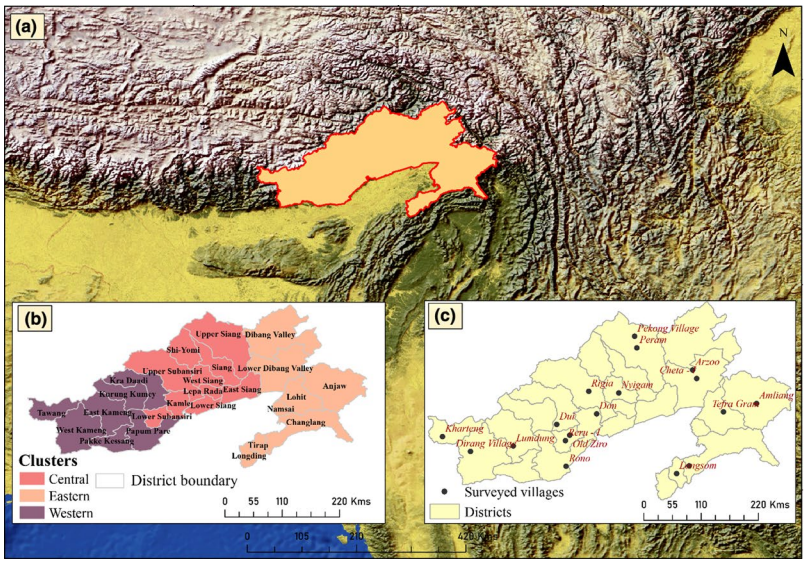
as, using livelihood vulnerability index (Panthi et al., 2016; Shah et al., 2013), household livelihood vulnerability (Baffoe & Matsuda, 2018), multidimensional vulnerability index (Rana & Routray, 2018), inherent vulnerability index (Rajesh et al., 2018) and hierarchical clustering on principal component (HCPC) analysis (Segnon et al., 2021), etc. For example, Giri et al. (2021) analysed regional vulnerability to climate change based on food, livelihood, health, resources, socio-economic support, coping strategy and infrastructure factors. Another study by Mehzabin and Mondal (2021) assessed the livelihood vulnerability for southwest coastal Bangladesh using six livelihood factors. It emphasises that LVI may be used by policy makers and practitioner for identifying the factors that lead to the livelihood vulnerability of the communities. Majumdar et al. (2022) analysed the IPCC-LVI of the rural households of Manikchak block in West Bengal. Their analysis indicated that riverbank erosion, which is dependent on the geographical characteristics of the area, is the main reason for the livelihood vulnerability of the riverine community. Other studies have incorporated socio-economic and biophysical factors for livelihood vulnerability analysis (Nong et al., 2022; Shahzad et al., 2021; Singha et al., 2020). However, a close examination of adaptation by local communities, generally based on how they perceive the risks, to mitigate the implications is required for understanding the factors that makes certain communities adaptive and resilient. Therefore, we have chosen a climate vulnerable state in the northeast India with scarce baseline research as a case study, of which we have elaborated in the following section, to explore these research gaps.

Inequality and poverty are salient conditions that increases climate related vulnerability. These conditions affect the ability of communities to cope with climate change induced impacts (Nath et al., 2020; Olsson et al., 2014). It is estimated that 5–15% of GDP in climate exposed countries, including India, will be at risk by 2050 (Eckstein et al., 2021). Maximum share of gross domestic product (GDP) in India is associated with agriculture and any reduction in the share raises the country's risk. Furthermore, it is projected that India will likely experience around 7% decrease in agricultural yields by 2050 (Woetzel et al., 2020). Changes driven by climate change are much evident in northeastern states of India. Decreasing rainfall and rising temperature trends over the eastern and southern parts of northeast India was detected since last several decades (Paul et al., 2019). In case of Arunachal Pradesh, the agriculture and animal rearing are the major livelihood activities. The population in the state is mainly rural and the districts located in the northern part provides a challenge of connectivity due to mountainous topography (Maiti et al., 2017). Unsustainable shifting cultivation, deforestation, mining and unplanned urbanization are also leading to environmental degradation in the region (Ravindranath et al., 2011). Thus, the present study carried out an indicator-based IPCC livelihood vulnerability assessment and perception analysis in Arunachal Pradesh, India. The major aim of this household level vulnerability assessment is to extend the understanding over how climate change influence on livelihood has been perceived by the local communities and to identify the factors inducing livelihood vulnerability in the study area.

Study area

Arunachal Pradesh is the largest state in the North-eastern states of India with an area of 83,743 km^2 (Fig. 1). According to Census of India (2011), population of Arunachal Pradesh was 1,383,727 with sex ratio of 938, maximum people living in rural areas (77.06%) and literacy rate in the state was 65.38% with male population literacy (72.55%) higher than female literacy (57.70%). There are around 26 major tribes and other sub-tribes in Arunachal Pradesh. Population density of this region is very less due to the harsh geographical conditions and mostly concentrated or recently migrated to the low-lying foothills. Due to its mountainous terrain, most of the parts of this region are inhospitable which with its low population density makes health services in the region rather scarce. Social structure of the tribes in Arunachal Pradesh is based on village panchayats, also called by regional names like *Kebang*, *Long*, *Mel*, etc. Arunachal Pradesh is also identified as one of the poor states in India during 2011–2012 with 34.67% of people living below poverty line (RBI, 2019).

Arunachal Pradesh has one of the lowest human development index (HDI) among the North-eastern states of India (Nayak, 2009). Traditionally, forest had been the main source of livelihood and people were



District	Block	Village
Anjaw	Hayuliang	Amliang
Dibang valley	Anelih-Arzu	Arzoo
Lower Dibang Valley	Roing	Cheta - 1
West Kameng	Dirang	Dirang
Kamle	Puchigeko	Don
Kra Daadi	Palin	Dui
Tawang	Lumla	Kharteng
Changlang	Bordumsa	Kherem Bisa
Longding	Niausa	Longsom
East Kameng	Bana	Lumdung
West Siang	Basar	Nyigam
Lower Subansiri	Ziro	Old ziro
Upper Siang	Tuting	Pekong village
Upper Siang	Geku	Perum
Lower Subansiri	Ziro-I	Reru-I
Upper Subansiri	Taliha	Rigia
Papum Pare	Doimukh	Rono
Lohit	Tezu	Tafrogam

Fig. 1 Site map: **a** location of Arunachal Pradesh, **b** various clusters and districts and **c** surveyed villages. Source: Prepared by authors in ArcGIS v.10.7.1

highly dependent on the forest resources. But due to the restrictions on timber operation by the Supreme Court of India in 1996, the people in the region have shifted to agriculture and cost a huge revenue loss for the state government. Population is mainly engaged in agriculture for their livelihood while they have artistic/craftsmanship skills practiced through various crafts like, painting, weaving, pottery, basket making, smithy work, etc. Wet rice cultivation and paddy cum pisciculture is the most practiced crop cultivation option by the tribes in the state.

Methods

A mix method analysis has been carried out in this paper. Livelihood vulnerability index (LVI) was prepared using the various indicators of exposure, sensitivity and adaptation while perception of the respondents on climate change influence on livelihood were qualitatively examined. A detailed methodological framework is presented in Fig. 2.

Selection of households for socio-economic data collection

The sampling process consisted of three stages. In the first stage the whole state of Arunachal Pradesh was divided into three clusters based on its geographical extent (Table 1). In stage 2, villages were stratified based on population range (High population > 1000, Moderate > 500 and Low < 500) and one village was selected from each district such that each cluster had equal distribution of high, moderate, and low population. A total of 7 districts were identified in western, 10 districts in central and 8 districts in eastern clusters. Villages among these districts were classified into three categories based on total population i.e., high, moderate and low. Thus, 6 villages from the population categories were selected for household sampling. In this way a total of 18 villages were selected. In the last stage household selection was made. From each village, a total of 25 households were randomly chosen. Thus, a total of 450 households were surveyed. The perception of the households on varied implication climate change as general and specifically on livelihood were recorded using a semi-structured questionnaire (details provided as supplementary).

Qualitative data analysis

An open-ended question to the main questionnaire were added to bring forth the insights of the local communities on how climate change has influenced their livelihood. The interview was conducted in

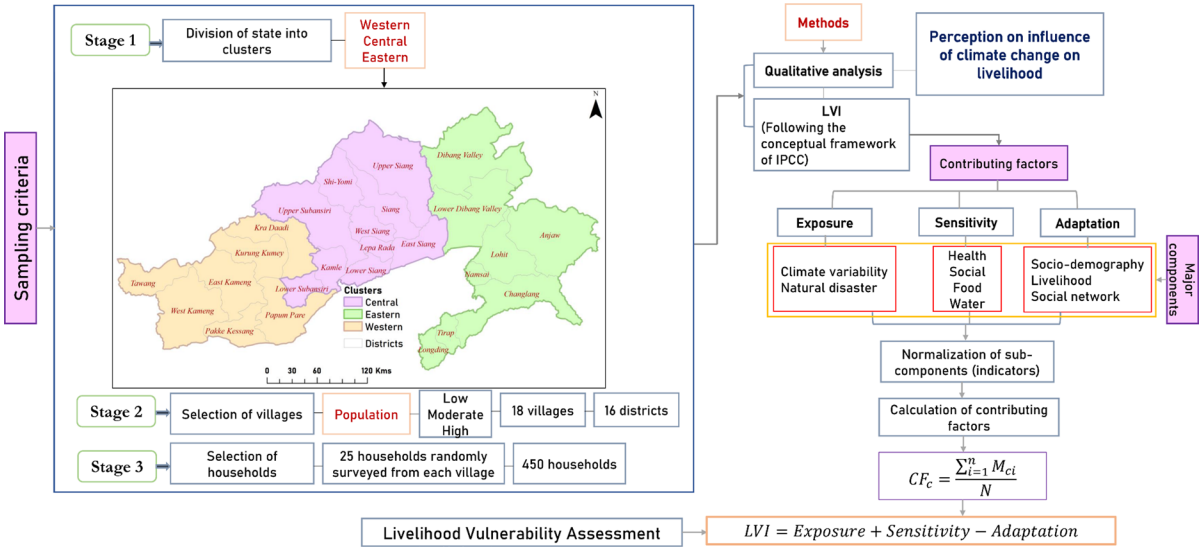


Fig. 2 Methodological framework of the study. Source: Authors

Table 1 Division of state into three clusters

Clusters	Area (ha)	Area (km^2)
Eastern	3,122,607	31,226.07
Central	2,787,010	27,870.10
Western	2,464,683	24,646.83
Total	8,374,300	83,743

local tribal languages such as *Nyishi*, *Apatani*, *Mishmi*, *Tagin*, *Assamese* and Hindi language which was later transcribed in verbatim and translated into English language for the analysis. The semi-structured questions allowed the participants to express their perceptions (Hennink et al., 2020) about how their everyday lives and livelihoods affected by the climate change and we received wide range of opinions; some of which are quoted verbatim with pseudonyms to protect their identity. The interview responses were investigated through the Atlas.ti8, a qualitative software, in two rounds to accomplish the data coding (Hennink et al., 2020; Saldana, 2011). Both the deductive and inductive codes were developed from the interview transcripts. The deductive codes were created from the research theme and theoretical background of the study (Table 2). On the other hand, inductive codes such as change in lifestyle, cropping pattern, growing newer crops and efficient adaptation were fashioned out of the participants' interviews with additional perceptions on the research theme. In the next phase, both the codes were arranged and merged into code groups, also known as code families, for further examination (Saldana, 2011). The code families, combination of a number of codes, were formed for the rounded understanding of the climate change effect on livelihoods of the local communities. Codes were explained with linking and comparing different opinions and contexts of the participants (Jahangir et al., 2021).

Calculation of livelihood vulnerability index

The livelihood vulnerability index (LVI) was computed incorporating the contributing factors considered by IPCC as a function of exposure, sensitivity and adaptation (Cardona et al., 2012). The exposure includes two major components i.e., climate variability and natural disasters. For quantifying the sensitivity, the major components were health, social, food and water while socio-demography, livelihood and social network components (Hahn et al., 2009) were ascertained under adaptation. The indicators under these components are presented in Table 3.

All the indicators were normalized for the computation of major component using the following equation:

Table 2 List of code family and codes for influence of climate change

Code family	Codes	Example quotations
Influence on livelihoods	Decrease in yield	*The rising temperature due to climate change has caused huge damage to agricultural production; it significantly decreased the yields* (Kelsang Tsomo, 48, Farmer)
	Loss of livestock	*Climate changes increased the temperature and caused irregularities in rainfall which in turn, caused losses of livestock.* (Sonam Wangdue, 57, farmer)
	Increase diseases	*With changing climate multiple diseases have come up. Many health issues such as mosquito infestation have increased due to changing pattern of temperature and rainfall* (Aming Tamut, 67, Farmer)
	Increase occurrence of landslides	*Frequent occurrence of natural disaster particularly the landslides can be seen due to climate change. The sudden cloudburst caused torrential precipitation causing more widespread landslides. Few years back we saw flash floods that huge loss of the forested and agricultural land due to landslide and soil erosion* (Kabom Taku, 52, farmer)

All names are pseudonyms

Table 3 Major components and indicators under contributing factors of LVI

Contributing factors of LVI	Major component	Sub-components (indicators)
Exposure	Climate variability	Increase in rainfall in last 10 years, increase in temperature in last 10 years, damages to forest and mountainous vegetation, changes in streams and channels and glacial retreat
	Natural disaster	Increase landslide due to extreme precipitation and increasing episodes of disasters (cloudburst, floods and landslides)
Sensitivity	Health	Females, older adults and children sensitivity to climate change and disasters, Households' not receiving special care for pregnant/lactating women and older adults,
	Social	Open drainage, muddy houses, migration, households not possessing landholdings and households with asset losses
	Food	Damage to agricultural lands, soil erosion on hilly tracts, livestock losses and decrease in yield
	Water	Depletion and contamination of groundwater and decrease in the supply of freshwater
Adaptation	Socio-demography	Literate households, cemented households, households having electricity, kitchen, LPG connection, drinking water and Sanitation (toilet) facility, households having income > 18,000 and households possessing > 3 ha landholdings
	Livelihood	Households engaged in small scale industry, trade, restaurant and hotel services, watershed management practices, creation of pastures for livestock, use of less water retention crops, utilization if pesticide and insecticide for protecting yields, agro-pastoral activities, plantation and terrace farming and water harvesting
	Social network	Efficacy of Local police announcement and information from friends and relative outside the villages for early warning to disaster, community-based organization, local stakeholders and NGO workers/self-help groups (SHGs) in knowledge sharing

$$N_{sc} = \frac{\int_x - \int_{\min}}{\int_{\min} - \int_{\max}}$$

where, N_{sc} is the sub-component indicators derived from the household survey, $\int_x$ is the value of indicator while $\int_{\min}$ is the minimum and $\int_{\max}$ is the maximum value of each indicator.

The average value of each sub-component was calculated as:

$$X_{sc} = \frac{\sum_{i=1}^{n} N_{sc}}{n}$$

where, X_{sc} is the index value obtained by aggregation of indicators ($\sum_{i=1}^{n} N_{sc}$) and divided by the total number of indicators (n).

After calculation of the sub-components, the major components were computed using the following equation:

$$CF_c = \frac{\sum_{i=1}^{n} M_{ci}}{N}$$

In the above equation, CF_c refers to the contributing factors i.e., exposure, sensitivity and adaptive capacity calculated by the aggregation of sub-components (M_{ci}) and divided by the total number of major components (N) in each contributing factor.

After the calculation of exposure, sensitivity and adaptation, the livelihood vulnerability index (Jakariya et al., 2020) was calculated as:

$$LVI = Exposure + Sensitivity - Adaptation$$

LVI was ranged into three categories including low (0.15–0.46), moderate (0.47–0.78) and high (0.79–1.09) vulnerability based on equal interval classification.

Pearson correlation was also performed between major component and LVI to examine the significant factors of livelihood vulnerability (Table 5).

Results

Characteristics of the sampled households

Of the total sampled households, around 66% were males while 34% were females. Average age of the studied population was 42 years. The minimum age among the sampled household was identified 16 while the maximum age was 72 years. The sampled respondents were classified into early working age (15–24), prime working age (25–54), mature working age (55–64) and older adults (above 65). Most of the respondents (79%) belonged to prime working age followed by mature working (15%), early working (4%) and older adults (2%). More than half of the respondents (53%) were found practicing indigenous religion followed by Christianity (23%), Buddhism (19%) and Hinduism (6%). Among the literate respondents, nearly 26% studied respondents were educated up to primary level followed by matric (20%), intermediate (10%), graduation (15%), post-graduation (3%) and religious training (1%). In case of occupation, most of the studied household heads were found engaged in cultivation (43%) while 21% respondents work as agricultural labourers and 4% were found engaged in households' industry. Another major share of respondents was found engaged in other working activities (32%) including government employee, business, distributor (FCI), driver, teacher, shop keepers, construction labours, carpenter, etc. (Fig. 3e). Largely the sampled households (41%) were found earning less than 6000 for a month followed by > 18,000 (27%), 6000–12,000 (19%) and 12,000–18,000 (12%). Lorenz curve analysis revealed relative income equality (0.28) in income among the sampled households (Fig. 4). The descriptive statistics of the sampled households are presented in Table 4.

Perception of studied households on climate change influence on livelihoods

Impact on agriculture: "climate change affected the agricultural yields"

The local communities, mainly engaged in agricultural activities, reported that the climate change induced extreme events such as cloud burst and subsequent torrential rainfall not only damaged the agricultural crops but also reduced the crop productivity over the years. Since over 80% of agricultural land are under rainfed cultivation, the erratic weather has caused either too much rain in short period of time or less rain during the crop cultivation that adversely impacted the crop yield. Besides, changing temperature also brought about various diseases which have caused decrease of yields. As a result, people are using more and more chemical fertilizers that further degrade the soil fertility and reduced yields after certain point.

> Climate change has influenced almost everything. Changes in rainfall and temperature are visible. The temperature has increased these days which have resulted in decreasing yields. We see either too much or too little rainfalls, often at the wrong time and is leading to water scarcity, and crop failure. Besides, multiple

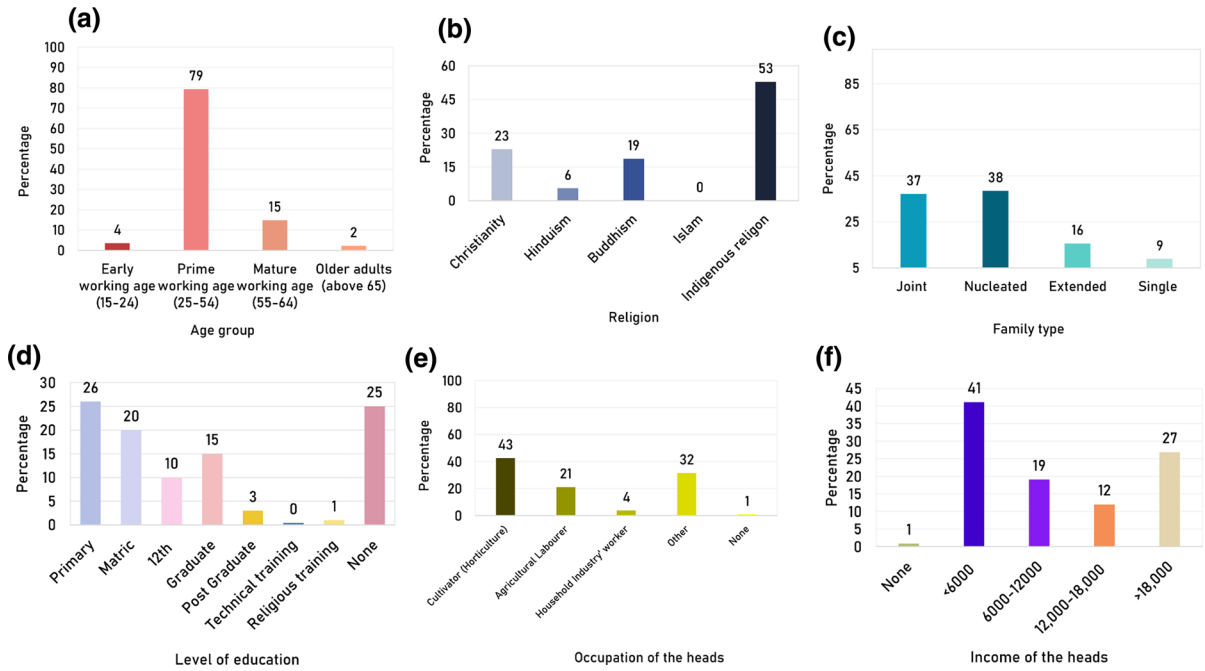


Fig. 3 Characteristics of the sampled households: **a**) age group, **b**) religion, **c**) family type, **d**) level of education, **e**) occupation of the heads and **f**) income of the heads. Source: Based on field sampling

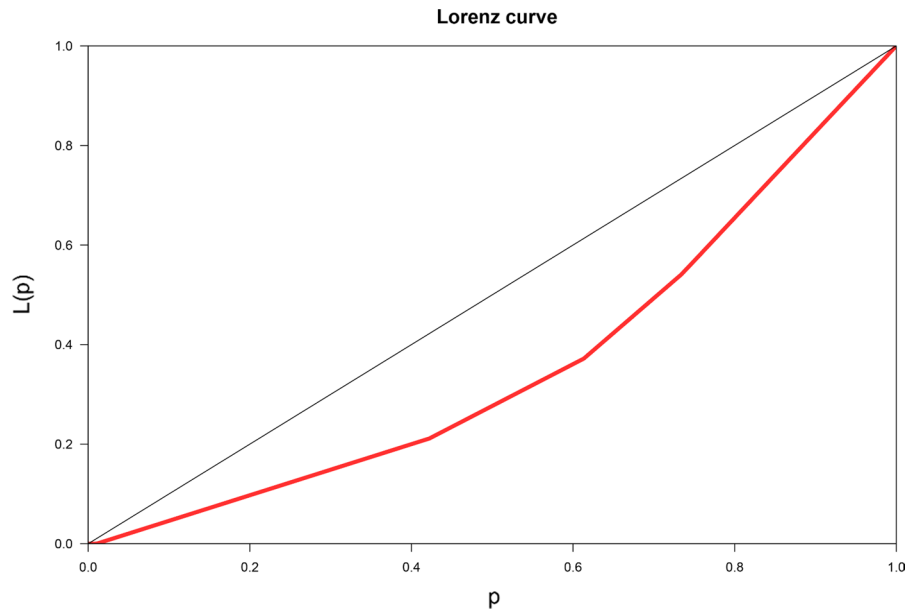


Fig. 4 Lorenz curve of income inequality among the studied households. Source: Based on field sampling

diseases have come up with climate change which have also decreased the agricultural yields (Boga Laye, 57, farmer in Nyigam village of Upper Siang district).

Loss of livestock

Domestic livestock, particularly cattle, plays multiple roles in the livelihoods of the local communities

Table 4 Descriptive statistics of the sampled households

Household characteristics	Categories	Mean	Standard deviation
Sex	Male	1.32	13.96
	Female	0.68	7.20
Caste	General	0	0.07
	OBC	0.03	0.30
	SC	0.01	0.12
	ST	1.96	20.72
Family type	Joint	0.74	7.86
	Nucleated	0.77	8.14
	Extended	0.31	3.31
	Single	0.18	1.90
Marital status	Married	1.66	17.62
	Never married	0.20	2.18
	Widowed	0.09	0.96
	Divorced/separated	0.04	0.45
	Remarried	0	0
Housing structure	Muddy house	0.04	0.40
	Semi cemented house	0.70	7.39
	Fully cemented house	0.33	3.54
	Grass/bamboo/others	0.93	9.88
Housing type	Good	0.97	10.30
	Liveable	1.02	10.86
	Dilapidated	0	0
Housing facilities	Electricity	2.00	21.14
	Kitchen	1.88	19.97
	LPG connection	1.73	18.33
	Drinking water	1.97	20.91
	Sanitation (toilet)	1.97	20.86
	Wastewater outlet (drainage)	1.16	12.27
Drainage type	Open	0.99	10.49
	Closed	0.15	1.57
	No drainage	0.86	9.13
Households possessing landholdings	Yes	1.80	19.08
	No	0.20	2.09
Size of landholdings (hectares)	None	0.20	2.09
	< 1 ha	0.58	6.17
	1–2 ha	0.70	7.44
	2–3 ha	0.25	2.65
	> 3 ha	0.27	2.89
Households having livestock	Yes	1.39	14.71
	No	0.61	6.45

Table 4 (continued)

Household characteristics	Categories	Mean	Standard deviation
Crops grown	Rice	1.54	16.36
	Maize	0.67	7.06
	Millet	0.37	3.97
	Wheat	0.01	0.16
	Pulses	0.11	1.20
	Sugarcane	0.04	0.45
	Oilseeds	0.05	0.59
	Herbs	0.39	4.11
Distance of field from market	< 1 km	0.12	1.24
	2–3 km	0.36	3.83
	4–5 km	0.16	1.67
	> 5 km	0.39	4.20
	None	0.97	10.30
Purpose of cultivation	None	0.24	2.51
	Commercial	1.40	14.85
	Subsistence	0.36	3.83

as majority of them are dependent on agriculture related activities. The farmers and cattle ranchers perceived that climate change, with changing temperature and rainfall, led to decline in forage quality and heat stress, has negatively affected the livestock rearing in the region. Since grassland area has reduced people find it difficult to graze their cattle and gradually, they reduce the number of domestic animals. Majority of the participants viewed that they lost *Mithun* (an important bovine species in hilly tracts of northeast India), which has significant role in socio-economic and cultural life of the local communities, due to lack of and declining forest fodders and grass in the mountains.

> Climate change has increased flood which have affected livestock. Moreover, climate change with unbearable summer, impact on loss of livestock. Earlier we used to have a number of Mithun but nowadays we have only few since the grazing land and jungle fodders are decreasing (Orik Paron, 38, Perum village of Upper Siang).

Increase in diseases

Majority of the participants viewed that climate change also led to adverse impact on the health with increasing temperature associated with high humidity that make environment congenial for diseases particularly mosquito borne diseases. The changing climatic variables such as temperature, rainfall and relative humidity significantly contributed to the transmission of malaria in the region by altering the life cycle of mosquitoes and parasite development. The field observation and interviews also revealed that high altitude regions have become vulnerable to vector borne diseases such as malaria due to change in the temperature. Since the State of Arunachal Pradesh experience frequent climate variability which influence the ecology of malaria, it also increases the morbidity and mortality.

> Various diseases have increased with climate change which have caused increased expenditure for health. We have to travel a long distance to avail medical facilities. We see new diseases have come up with climate change that were never there (Kaling Taku, 42, farmer from Perum village in Upper Siang district).

Increase occurrence of landslides

Short term torrential downpour along with heavy rainstorm and cloud-burst adversely impact the

fragile geomorphology of hilly Arunachal Pradesh by eroding soil and widespread landslides. The reckless deforestation along with other anthropogenic activities such as hydro power projects in lower Arunachal Pradesh have caused climate variability. Many of the participants viewed those increasing settlements and changing agricultural pattern in the hilly tracks have immense bearing effect in triggering landslides.

> One of the major causes of climate change is deforestation. The man-made natural hazard like landslide is killing indigenous people by destroying the land they depend on for their survival. More frequent and intense rainfall events due to climate change has caused landslides, which is destroying towns to cutting off drinking water and transportation networks (Beta Menjo, 54, vegetable seller from Arzoo village of Dibang valley).

In addition, the local communities also expressed that they experienced changes in their everyday lives due to climate change induced extreme events. They have to adopt different adaptation pathways to address the emerging issues caused by the climate change which changed the life course events. Due to its fragile geomorphology and biodiversity, even a slight change in the climatic condition have a major change in the livelihoods of the local communities particularly on those who are engaged in agriculture, livestock & allied activities.

> Seriously affecting the way of our life. With each passing day, there has been serious change in the climate which has led to shifting of plans of our work execution at site since the seasonal changes are irregular (Lobsang Sharchokpa, 39, farmer from Dirang village in West Kameng District).

Livelihood vulnerability index (LVI)

The contributing factors of LVI analysis revealed varying degrees of exposure, sensitivity and adaptation among the surveyed villages (Table 5; Fig. 7). In case of exposure, the high exposure was identified in Perum followed by Dui, Rigia, Pekong, Rono, Arzoo, Amliang, Don, Nyigam and Reru-I villages. Frequent occurrence of extreme weather events and climate variability made these villages highly exposed. Old Ziro village was identified under moderate exposure followed by Dirang, Lumdung, Cheta-1 and Kharteng villages due to moderate influence of disasters and climate variability. In case of low exposure, Kherem Bisa village was found under low vulnerability followed by Longsom and Tafragam villages.

Table 5 Degree of contributing factors and livelihood vulnerability in the surveyed villages

Villages	Exposure	Adaptation	Sensitivity	LVI
Amliang	0.85	0.55	0.37	1.03
Arzoo	0.86	0.59	0.38	1.07
Cheta-1	0.50	0.26	0.40	0.36
Dirang	0.51	0.53	0.73	0.31
Don	0.83	0.59	0.68	0.75
Dui	0.90	0.47	0.52	0.85
Kharteng	0.44	0.42	0.69	0.17
Kherem Bisa	0.18	0.34	0.37	0.15
Longsom	0.21	0.43	0.29	0.34
Lumdung	0.51	0.20	0.32	0.39
Nyigam	0.82	0.57	0.56	0.83
Old Ziro	0.53	0.50	0.64	0.39
Pekong Village	0.88	0.68	0.53	1.03
Perum	0.93	0.62	0.45	1.09
Reru-I	0.80	0.49	0.77	0.52
Rigia	0.89	0.54	0.71	0.72
Rono	0.86	0.63	0.68	0.81
Tafragam	0.38	0.47	0.39	0.47

High sensitivity was identified in Pekong village followed by Rono, Perum, Don, Arzoo, Nyigam, Amliang, Rigia and Dirang villages. Migration due to disasters, open drainage, muddy housing structure, not having landholding, deterioration of groundwater and decrease in the supply of the freshwater caused higher sensitivity in these villages. Old Ziro villages was found under moderate sensitivity followed by Reru-I, Dui, Tafrogam, Longsom and Kharteng villages. Low level of health and food components including damage to agricultural lands, soil erosion on hilly tracts, livestock losses and decrease in yields. Low sensitivity was found in Lumdung followed by Kherem Bisa and Cheta-1 villages (Table 5; Fig. 6).

Higher literacy, adequate housing amenities (electricity, kitchen, LPG connection, drinking water, sanitation), engagement in alternative livelihood practices and better social network contributed higher

adaptation in Reru-I village followed by Dirang, Rigia, Kharteng, Don, Rono and Old Ziro villages. These villages revealed high performance in socio-demography and livelihood components where most of the households have housing amenities and adapting alternative livelihoods. Moderate adaptation was found in Nyigam village followed by Pekong and Dui villages. These villages have moderately performed in socio-demography and livelihood components. Low adaptation was found in Longsom village followed by Lumdung, Amliang, Kherem Bisa, Arzoo, Tafrogam, Cheta-1 and Perum villages. Low performance in socio-demography, livelihood and social network components were found to be the determinants of low adaptation in these villages (Figs. 5, 6).

Livelihood vulnerability among the villages were classified into three categories including not vulnerable (0.15–0.46), moderate (0.47–0.78) and highly vulnerable (0.79–1.09). LVI analysis revealed high vulnerability in Perum village followed by Arzoo, Pekong Village, Amliang, Dui, Nyigam and Rono villages due to high exposure, sensitivity and low adaptation. Moderate vulnerability was found in Don village followed by Rigia, Reru-I and Tafrogam villages due to high sensitivity and low adaptation (Fig. 7; Table 4). Low livelihood vulnerability was found in Kherem Bisa village followed by Kharteng, Dirang, Longsom, Cheta-1, Old Ziro and Lumdung villages. The perception of the households on various implications of climate change and disasters, examined on Likert scale (very high to very low), revealed a higher agreement on the increasing episodes of disasters such as cloudburst, floods & landslides (28%) and damage to agricultural lands (48%). Moreover, higher sensitivity of male (61%), female (53%) and older adults (42%) to climate change and disasters were also observed among the sampled respondents. Decreases in freshwater supply (43%) was found to be moderately affecting. Changes in streams and channels (32%), soil erosion on hilly tracts (33%), depletion and contamination of groundwater (36%) and children sensitivity to climate change and disasters (31%) were found impacting low as disclosed by studied households (Fig. 8).

Correlation analysis revealed that climate variability, natural disaster, health, food and social components were found to be highly significant with LVI which suggest that these components contribute high livelihood vulnerability in the study area. These components were showed high association with each

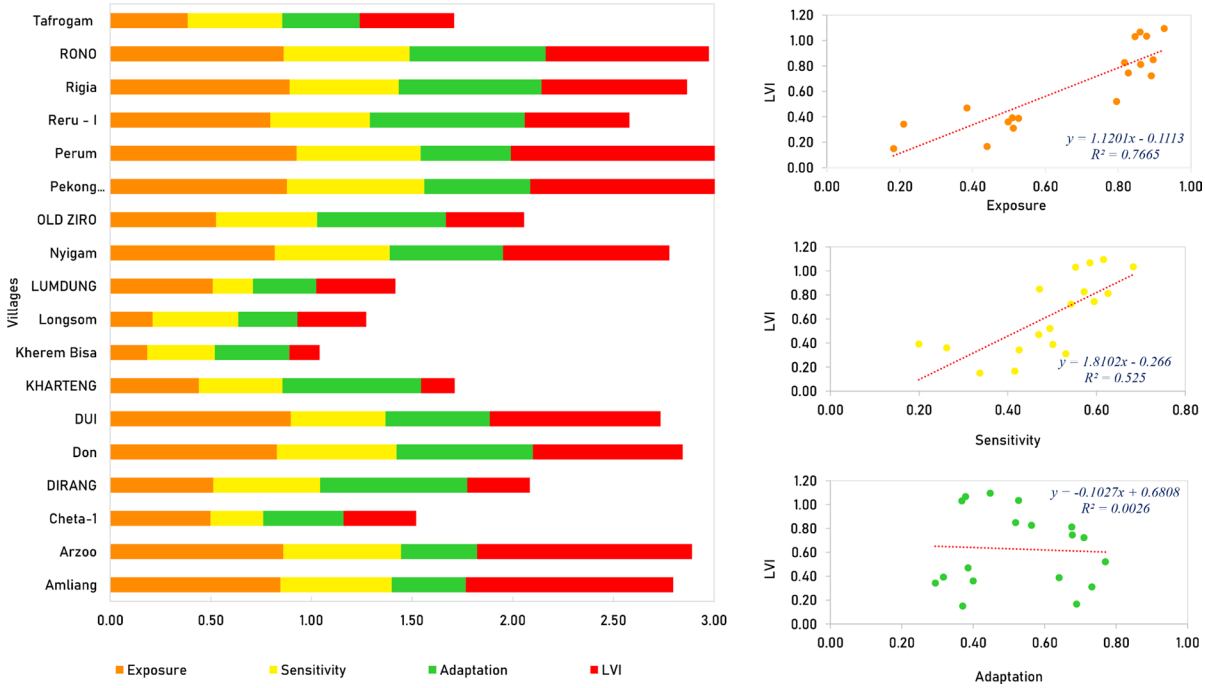


Fig. 5 LVI and contributing factors. Source: Based on LVI analysis

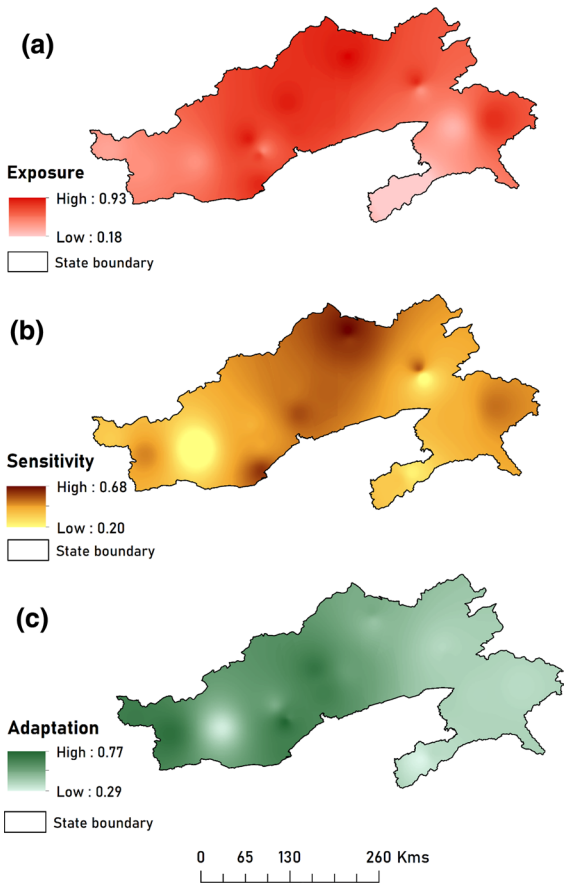


Fig. 6 Spatial distribution: **a**) exposure, **b**) sensitivity and **c**) adaptation. Source: Prepared by authors based on LVI assessment

other. However, only socio-demographic component was found negatively significant to health component (Table 6).

Discussion

Climate change being a great challenge of vulnerable communities has largely been recognized in many disciplines. Perception of the communities on the impacts of climate change plays an essential role in examining the risks that people are facing (Rühlemann & Jordan, 2021). Hence, this study analysed the livelihood vulnerability and explored the perception of the respondents on climate change influence on livelihood in an agro-based rural community of Arunachal Pradesh. Analysis of LVI in the Arunachal Pradesh revealed a concerning picture where the degree of exposure and sensitivity is a point of concern in many ways. Dui, Pekong, Perum and Rigia villages have observed high degree of exposure as climate variability and extreme weather events were found higher in these villages. Lower conditions of health, social, food and water components have induced high degree of sensitivity in Don, Perum, Arzoo, Amliang and Pekong Villages. Higher sensitivity of groups (females, children and older adults) to climate change and disasters, muddy housing structure, open drainage, assets losses during disasters, damage of agricultural lands, soil erosion, livestock losses, decreasing yield and decreasing supply of fresh water were identified the determinants of sensitivity. Moreover, small landholdings, dependency on agricultural productivity for livelihood and marginalization of land are the major determinants of relative income equality (Fig. 4) of the studied households (Das & Srivastava, 2021). Exposure was identified the main contributing factor inducing the livelihood vulnerability in the study area (Fig. 5).

The higher consensus among households on varying influence on climate change on livelihoods have also indicated how the changing climate is affecting the livelihood at a large extent (see "Perception of studied households on climate change influence on livelihoods"; Fig. 9). More than half of the respondents (51%) appears to have knowledge of the climate change (Fig. 9). The higher agreement of respondents on climate variability, increasing in temperature, extreme rainfall and increasing disaster events suggest that the climatic conditions is changing drastically leaving an imprint on the local communities. About 29% respondents have explained that temperature have become extreme while rainfall has become more unpredictable (Fig. 9). Decrease in yields, loss of soil fertility and human health (25%), frequent landslides and floods (10%) and livestock losses and decreasing yields (8%) were perceived by the study population. Nearly (6%) respondents also have identified that infectious diseases have also increased due to changing climate largely impacting the health which corroborates with other studies (Upadhyayula et al., 2015). Many scholars have also highlighted the impacts of changing climate in the northeastern states of India especially on the livelihood (Bhalerao et al., 2021; Paul et al., 2019).

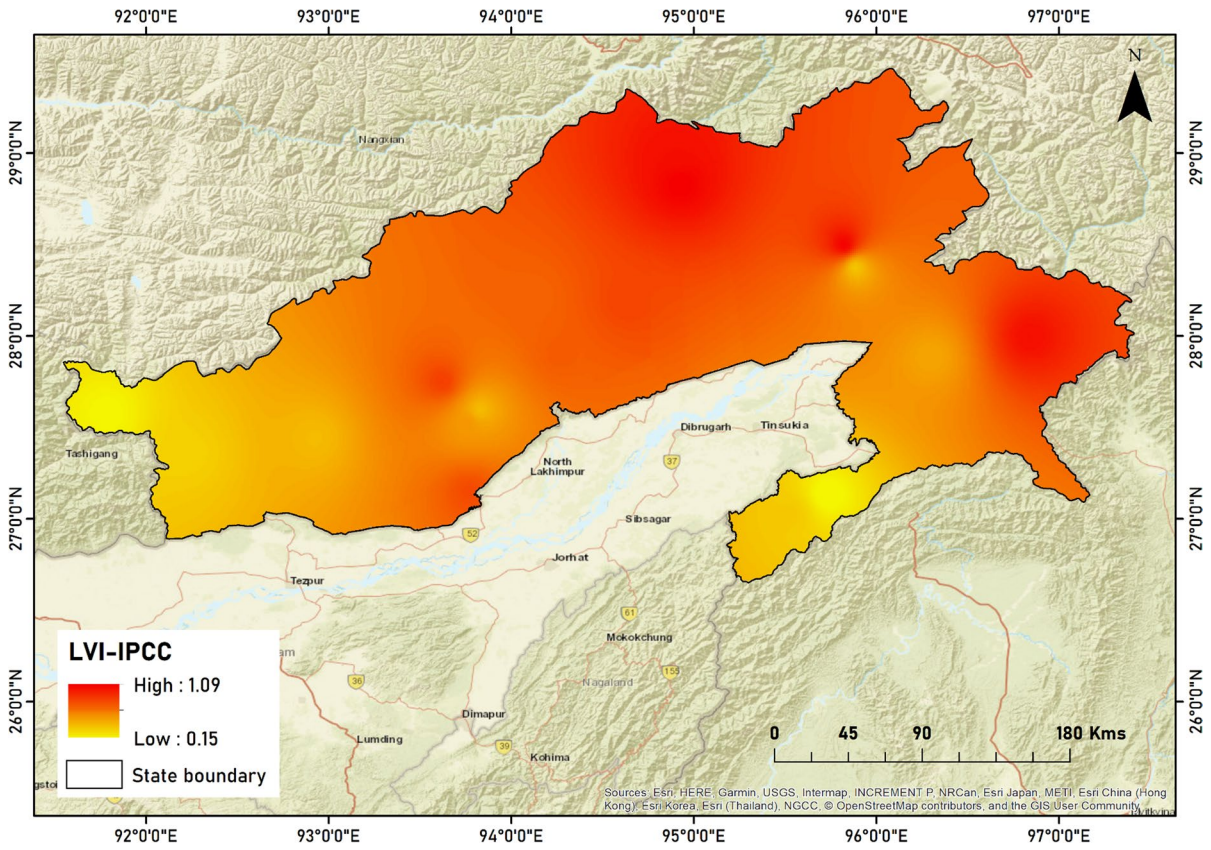


Fig. 7 Spatial distribution of LVI-IPCC in Arunachal Pradesh. Source: Based on LVI analysis

Biggs et al. (2018) identified that climate change has affected the tea production in the Assam posing a threat to the agricultural sector. Similarly, Sati and Lalrinpuia (2018) indicated that the climate change has led to decrease in the average yield of horticultural. Agricultural, the mainstay of Arunachal Pradesh, is highly vulnerable to climate change. The challenging terrain condition and subsistence nature of farming also the determinant of the overall development of the region (Bhagawati et al., 2017). Some projections over the state have also projected increase in maximum temperature from 2.2 to 2.8 °C and minimum temperature from 1 to 2.6 °C by 2030. This climate change induced increase in temperature may also likely to impact the biodiversity, water resources and forests in the study area (Deka et al., 2013). The frequency of hydrological and geological hazards has also increased with the climate change (Sheth, 2020). Bhagawati et al. (2017) also stressed that inadequate investment, undulating topography, poor development, traditional cultivation practices and climate change are providing barriers to the development of agriculture sector in the state. Perception of the local communities on climate change implication is gaining magnetism among the scientific community. Quantitative methods are important in explaining the outcomes while the qualitative assessment provides a complete picture of the implications faced by the local communities (Bui et al., 2020). Thus, this study offered an in-depth picture of the livelihood vulnerability in the state and perceptions that how climate change has influenced the livelihood of the local communities in the study area. The glimpse of the surveyed villages was presented in Fig. 10.

Knowledge of the respondents about the climate change and its implication suggest that the communities are connected to information sources in spite of the less educated. However, the undulating terrain and geographical alienation offer challenges to adaptation. The surveyed villages were prioritized based on LVI

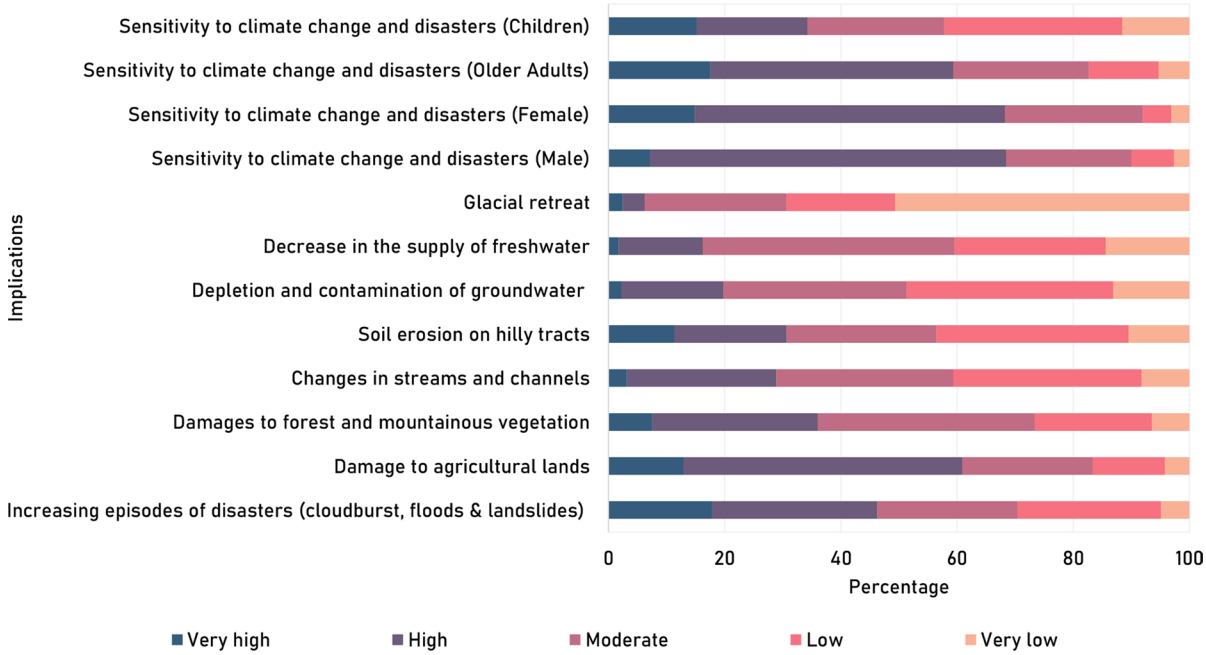


Fig. 8 Households' perceptions on implications of climate change and disasters. Source: Author analysis

and contributing factor analysis (Table 7). All the villages, except Kharteng, Dirang, Longsom, Cheta-1, Old Ziro and Lumdung villages require attention for lessening the degree of exposure in these villages. Exposure of the communities in these areas can be reduced by providing effective early warning system during disasters and making the disaster resilient structures. Amliang, Arzoo, Dirang, Don, Dui, Kharteng, Longsom, Nyigam, Old Ziro, Pekong Village, Perum, Reru-I, Rigia, Rono and Tafrogam villages require priority for lessening the level of sensitivity. Sensitivity in these villages may be minimized through providing essential care to children, female and older adults during extreme weather events. About 60% respondents have also disclosed that *Asha* workers under National Rural Health Mission (NRHM) are providing essential aids during pregnancy and lactating period of the mothers including free ante natal check-ups. Provision of essential healthcare facilities to females, children and older adults, improving basic housing amenities and government assistance to the people for agricultural and livestock losses may help in minimizing sensitivity. Moreover, in case of improving adaptation the Amliang, Arzoo, Cheta-1, Kherem Bisa, Longsom, Lumdung, Perum and Tafrogam villages need special attention.

Alternative livelihood activities such as horticulture, handicrafts, small scale industries, watershed management practices, strengthening the transport network and infrastructure may help in increasing the coping capacity of the people in these areas. LVI assessment revealed that Amliang, Arzoo, Don, DUI, Nyigam, Pekong Village, Perum, Reru-I, Rigia, Rono and Tafrogam villages accord priority for lessening the degree of exposure and sensitivity and enhancing the coping capacity of the communities. The state government is also encouraging people for horticulture and cultivation of cash crops. The central government has also initiated funds for providing rural employment in the state under Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA). The government has also initiated funds for housing structures under the *Pradhan Mantri Awaas Yojana Gramin* (PMAY-G) in various districts of Arunachal Pradesh (Ministry of Rural Development, 2021). Much less attention has been paid at regional scale climate change implications on local communities. Recently, the state has adopted a declaration on climate change, built on five pillars i.e., environment, forest and climate change, health & wellbeing of all, sustainable and adaptive living, livelihoods and opportunities and evidence generation and collaborative action for promoting climate resilient development.

Table 6 Relationship between LVI and major components

Variables	Climate variability	Natural disaster	Health component	Social component	Food component	Water component	Socio-demography	Livelihood	Social network	LVI
Climate variability	1	0.788**	0.296	0.737**	0.655**	0.299	−0.028	0.502*	0.519*	0.759**
Natural disaster	0.788**	1	0.225	0.587*	0.566*	0.158	−0.025	0.198	0.416	0.868**
Health component	0.296	0.225	1	0.211	0.384	−0.036	−0.604**	0.140	0.304	0.402
Social component	0.737**	0.587*	0.211	1	0.457	0.037	0.256	0.468	0.405	0.493*
Food component	0.655**	0.566*	0.384	0.457	1	0.064	−0.176	0.503*	0.239	0.611**
Water component	0.299	0.158	−0.036	0.037	0.064	1	0.182	0.057	0.170	0.318
Socio-demography	−0.028	−0.025	−0.604**	0.256	−0.176	0.182	1	0.061	−0.029	−0.232
Livelihood	0.502*	0.198	0.140	0.468	0.503*	0.057	0.061	1	0.682**	−0.036
Social network	0.519*	0.416	0.304	0.405	0.239	0.170	−0.029	0.682**	1	0.132
LVI	0.759**	0.868**	0.402	0.493*	0.611**	0.318	−0.232	−0.036	0.132	1

**Correlation is significant at the 0.01 level (2-tailed)

*Correlation is significant at the 0.05 level (2-tailed)

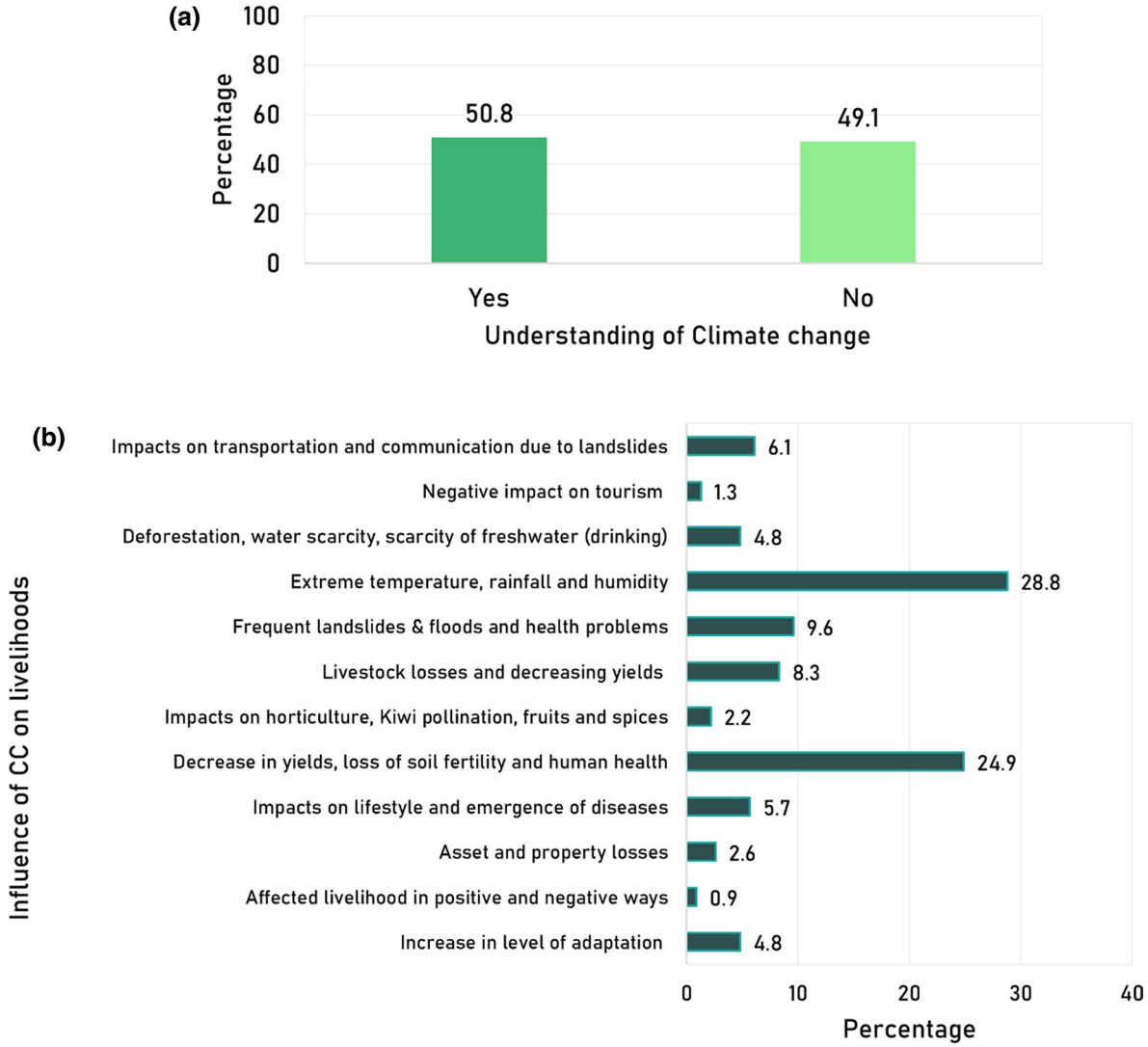


Fig. 9 **a** Respondents understanding on climate change and **b** perception on various influence of climate change on livelihood. Source: Based on respondents' perception

Conclusion

Assessment of livelihood vulnerability by taking into context the perceptions of agro-based communities to climate change risks is essential for adaptation planning and averting climate risks. Applying IPCC based livelihood vulnerability assessment along with the perception of households on climate change risks from a climate vulnerable state in India—Arunachal Pradesh—provided important insights for advancing knowledge on the impact of climate change on rural livelihoods and the need to alleviate their vulnerability including urgent measures that must be undertaken. Out of the total of 450 households surveyed from 18 villages located in the districts in western central and eastern parts of the state, perception of the respondents on climate change influence on livelihood revealed that decreasing yields, livestock losses, emergence of various diseases, increase in landslides and extreme climatic condition especially rising temperature. The LVI analysis indicated that villages that are highly vulnerable namely Arzoo, Pekong Village, Amliang, Dui, Nyigam and Rono villages village and moderately vulnerable, such as, Don, Rigia, Reru-I

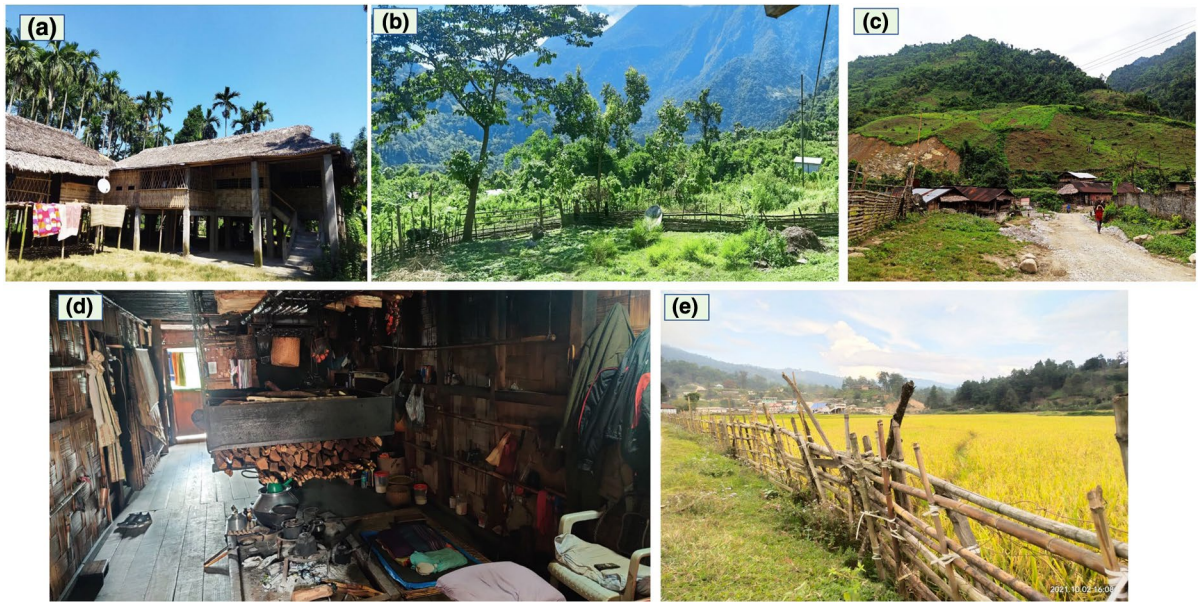


Fig. 10 Field photographs of surveyed villages: **a** A house in Kherem Bisa (Changlang), **b** a field in Amliang village (Anjaw), **c** houses in Dui village (Kra Daadi), **d** Inside view of a house in Old Ziro (Lower Subansiri) and **e** agricultural field in Cheta-1 village (Lower Dibang Valley). Source: Fieldwork

Table 7 Priority villages for contributing factors and LVI

Villages	Exposure	Sensitivity	Adaptation	LVI
Amliang	√	√	√	√
Arzoo	√	√	√	√
Cheta-1	√	–	√	–
Dirang	√	√	–	–
Don	√	√	–	√
Dui	√	√	–	√
Kharteng	√	√	–	–
Kherem Bisa	–	–	√	–
Longsom	–	√	√	–
Lumdung	√	–	√	–
Nyigam	√	√	–	√
Old Ziro	√	√	–	–
Pekong village	√	√	–	√
Perum	√	√	√	√
Reru-I	√	√	–	√
Rigia	√	√	–	√
Rono	√	√	–	√
Tafragam	–	√	√	√

and Tafrogam villages have high exposure, high sensitivity and compounded with less adaptation. The study shows that climate variability, natural disaster, health, food and social components are the key contributing components of livelihood vulnerability in the study area. This livelihood vulnerability assessment has helped in prioritizing the villages for lessening the exposure, sensitivity and increasing the adaptation capacity. Qualitative appraisal of influence of climate change on livelihood assisted in understanding the critical implications that the studied population are facing in the study area.

The higher agreement on increasing disasters, damage of agricultural land and sensitivity suggest the concerning situation of the respondents in the study area. Moreover, income inequality, impoverished housing structure, inadequate health facilities, less engagement of people in alternate livelihood, etc. are some of the barriers of the growth of the communities. Thus, this study suggests that community-based adaptation is required in addition to involving the assistance and support of the government for achieving the sustainable development goals especially in Arunachal Pradesh. Women participation in workforce, sustainable livelihood practices,

improvement in health and amenities, social infrastructure, education, equitable work participation and disaster preparedness may help in uplifting the socio-economic status of the communities in the study area. Although, this study did not consider the actual assessment of the implications of disaster susceptibility but households' perception on climate change induced livelihood implications provided a deeper insight of the varying implications. Furthermore, this study may be used as a baseline for framing the policy for the overall development of the region.

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Data availability The data used in this study for analysis was generated through household survey during the fieldwork of the project which can be made available on request of the corresponding author. International ethical standards are followed in handling the survey data and anonymised to protect the identity of the households surveyed.

Declarations

Conflict of interest There is no conflict of interest.

References

Akanwa, A. O., & Joe-Ikechebelu, N. (2019). The developing world's contribution to global warming and the resulting consequences of climate change in these regions: A Nigerian case study. Global warming and climate change. Retrieved from https://www.intechopen.com/chapters/70313.

Aribi, F., & Sghaier, M. (2021). Livelihood vulnerability assessment to climate change and variability: The case of farm households in South-East Tunisia. *Environment, Development and Sustainability, 23*(8), 12631–12658. https://doi.org/10.1007/s10668-020-01172-4

Baffoe, G., & Matsuda, H. (2018). An empirical assessment of households livelihood vulnerability: The case of rural Ghana. *Social Indicators Research, 140*(3), 1225–1257. https://doi.org/10.1007/s11205-017-1796-9

Bhagawati, R., Bhagawati, K., Jini, D., Alone, R. A., Singh, R., Chandra, A., Makdoh, B., Sen, A., & Shukla, K. K. (2017). Review on climate change and its impact on agriculture of Arunachal Pradesh in the Northeastern Himalayan region of India. *Nature Environment and Pollution Technology, 16*(2), 535.

Bhalerao, A. K., Rasche, L., Scheffran, J., & Schneider, U. A. (2021). Sustainable agriculture in Northeastern India: How do tribal farmers perceive and respond to climate change? *International Journal of Sustainable Development & World Ecology*. https://doi.org/10.1080/13504509.2021.1986750

Biggs, E. M., Gupta, N., Saikia, S. D., & Duncan, J. M. (2018). The tea landscape of Assam: Multi-stakeholder insights into sustainable livelihoods under a changing climate. *Environmental Science & Policy, 82*, 9–18. https://doi.org/10.1016/j.envsci.2018.01.003

Blackmore, I., Rivera, C., Waters, W. F., Iannotti, L., & Lesorogol, C. (2021). The impact of seasonality and climate variability on livelihood security in the Ecuadorian Andes. *Climate Risk Management, 32*, 100279. https://doi.org/10.1016/j.crm.2021.100279

Bui, Y., Lodhi, M. S., Chand, K., & Kuniyal, J. C. (2020). Public awareness, concerns and perceptions about anthropogenic impacts and climate change in Ranganadi river basin, Arunachal Pradesh, India. *International Journal of Environmental Sciences & Natural Resources, 26*(4), 148–154. https://doi.org/10.19080/IJESNR.2020.26.556195

Cannon, T., Twigg, J., & Rowell, J. (2003). Social vulnerability, sustainable livelihoods and disasters. Report to DFID conflict and humanitarian assistance department (CHAD) and sustainable livelihoods support office. p. 93

Cardona, O. D., Van Aalst, M. K., Birkmann, J., Fordham, M., Mc Gregor, G., Rosa, P., Pulwarty, R. S., Schipper, E. L., Sinh, B. T., Décamps, H., & Keim, M. (2012). Determinants of risk: exposure and vulnerability. In C. B. Field, V. Barros, T. F. Stocker, D. Qin, D. J. Dokken, K. L. Ebi, M. D. Mastrandrea, K. J. Mach, G.-K. Plattner, S. K. Allen, M. Tignor, & P. M. Midgley (Eds.), *Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups I and II of the intergovernmental panel on climate change (IPCC)* (pp. 65–108). Cambridge University Press.

Census of India. (2011). Arunachal Pradesh. Arunachal Pradesh Population, (2011). Retrieved November 30, 2021, from https://www.census2011.co.in/census/state/arunachal+pradesh.html#literacy

Das, M., Das, A., Momin, S., & Pandey, R. (2020). Mapping the effect of climate change on community livelihood vulnerability in the riparian region of Gangatic Plain, India. *Ecological Indicators, 119*, 106815. https://doi.org/10.1016/j.ecolind.2020.106815

Das, R., & Srivastava, R. (2021). Income inequality among agricultural households in India: A regression-based decomposition analysis. *Review of Development Economics, 25*(3), 1128–1149. https://doi.org/10.1111/rode.12758

Deka, B. C., Rangnamei, L., & Chakruno, M. (2013). Climate change and high-altitude wetlands of Arunachal Pradesh. *Current Science, 105*(8), 1037.

Eckstein, D., Künzel, V., & Schäfer, L. (2021). *Global climate risk index 2021. Who suffers most from extreme weather events? Weather-related loss events in 2019 and 2000–2019. Briefing paper*. Germanwatch.

Endalew, H. A., & Sen, S. (2021). Effects of climate shocks on Ethiopian rural households: An integrated livelihood vulnerability approach. *Journal of Environmental Planning and Management, 64*(3), 399–431. https://doi.org/10.1080/09640568.2020.1764840

Giri, M., Bista, G., Singh, P. K., & Pandey, R. (2021). Climate change vulnerability assessment of urban informal settlers in Nepal, a least developed country. *Journal of Cleaner Production, 307*, 127213. https://doi.org/10.1016/j.jclepro.2021.127213

Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The livelihood vulnerability index: A pragmatic approach to assessing risks from climate variability and change—A case study in Mozambique. *Global Environmental Change, 19*(1), 74–88. https://doi.org/10.1016/j.gloenvcha.2008.11.002

Hennink, M., Hutter, I., & Bailey, A. (2020). *Qualitative research methods*. Sage.

IPCC. (2021). Summary for policymakers. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), *Climate Change, (2021). The physical science basis. Contribution of working group I to the sixth assessment report of the intergovernmental panel on climate change*. Cambridge University Press.

Jahangir, S., Bailey, A., Hasan, M. U., Hossain, S., Helbich, M., & Hyde, M. (2021). "When I need to travel, I feel feverish": Everyday experiences of transport inequalities among older adults in Dhaka, Bangladesh. *The Gerontologist*. https://doi.org/10.1093/geront/gnab103

Jakariya, M., Rahman, A., Sayem, S. M., Saad, S., Alam, M. S., Sarker, S. R., Ali, M. S., & Akter, D. (2020). Development of livelihood vulnerability index for the coastal fishermen communities of Bangladesh using spatial information technique. *Groundwater for Sustainable Development, 11*, 100475. https://doi.org/10.1016/j.gsd.2020.100475

Koech, G., Makokha, G. O., & Mundia, C. N. (2020). Climate change vulnerability assessment using a GIS modelling approach in ASAL ecosystem: A case study of upper Ewaso Nyiro basin, Kenya. *Modeling Earth Systems and Environment, 6*(1), 479–498. https://doi.org/10.1007/s40808-019-00695-8

Mahmood, N., Arshad, M., Mehmood, Y., Faisal Shahzad, M., & Kächele, H. (2021). Farmers' perceptions and role of institutional arrangements in climate change adaptation: Insights from rainfed Pakistan. *Climate Risk Management, 32*, 100288. https://doi.org/10.1016/j.crm.2021.100288

Maiti, S., Jha, S. K., Garai, S., Nag, A., Bera, A. K., Paul, V., Upadhaya, R. C., & Deb, S. M. (2017). An assessment of social vulnerability to climate change among the districts of Arunachal Pradesh, India. *Ecological Indicators, 77*, 105–113. https://doi.org/10.1016/J.ECOLIND.2017.02.006

Majumdar, S., Das, A., & Mandal, S. (2022). River bank erosion and livelihood vulnerability of the local population at Manikchak block in West Bengal, India. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-021-02046-z

Mehzabin, S., & Mondal, M. S. (2021). Assessing impact of climate variability in southwest coastal Bangladesh using livelihood vulnerability index. *Climate, 9*(7), 107. https://doi.org/10.3390/cli9070107

Ministry of Rural Development, (2021). State performance report 2020–21 and action plan 2021–22. Retrieved December 1, 2021, from https://rural.nic.in/sites/default/files/StatePerformanceReport2020-21andActionPlan2021-22Volume2_15062021.pdf

Muringai, R. T., Naidoo, D., Mafongoya, P., & Lottering, S. (2020). The impacts of climate change on the livelihood and food security of small-scale fishers in Lake Kariba, Zimbabwe. *Journal of Asian and African Studies, 55*(2), 298–313. https://doi.org/10.1177/0021909619875769

Nath, S., van Laerhoven, F., Driessen, P., & Nadiruzzaman, M. (2020). Capital, rules or conflict? Factors affecting livelihood-strategies, infrastructure-resilience, and livelihood-vulnerability in the polders of Bangladesh. *Sustainability Science, 15*(4), 1169–1183. https://doi.org/10.1007/s11625-020-00818-6

Nayak, P. (2009). *Growth and human development in North-East India* (pp. 151–165). Oxford University Press.

Nong, H. T. T., Gan, C., & Hu, B. (2022). Livelihood vulnerability to climate change: A case of farm households in Northeast Vietnam. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-022-02201-0

Olsson, L., Opondo, M., Tschakert, P., Agrawal, A., & Eriksen, S. E. (2014). Livelihoods and poverty. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), *Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of working group II to the fifth assessment report of the intergovernmental panel on climate change* (pp. 793–832). Cambridge University Press.

Panthi, J., Aryal, S., Dahal, P., Bhandari, P., Krakauer, N. Y., & Pandey, V. P. (2016). Livelihood vulnerability approach to assessing climate change impacts on mixed agro-livestock smallholders around the Gandaki River Basin in Nepal. *Regional Environmental Change, 16*(4), 1121–1132. https://doi.org/10.1007/s10113-015-0833-y

Paul, A., Deka, J., Gujre, N., Rangan, L., & Mitra, S. (2019). Does nature of livelihood regulate the urban community's vulnerability to climate change? Guwahati city, a case study from North East India. *Journal of Environmental Management, 251*, 109591. https://doi.org/10.1016/j.jenvman.2019.109591

Rajesh, S., Jain, S., & Sharma, P. (2018). Inherent vulnerability assessment of rural households based on socio-economic indicators using categorical principal component analysis: A case study of Kimsar region, Uttarakhand. *Ecological Indicators, 85*, 93–104. https://doi.org/10.1016/j.ecolind.2017.10.014

Rana, I. A., & Routray, J. K. (2018). Multidimensional model for vulnerability assessment of urban flooding: An empirical study in Pakistan. *International Journal of Disaster Risk Science, 9*(3), 359–375. https://doi.org/10.1007/s13753-018-0179-4

Rangel-Buitrago, N., Gracia, C. A., Anfuso, G., & Bonetti, J. (2020). GIS hazard assessments as the first step to climate change adaptation. *Climate change, hazards and adaptation options* (pp. 135–146). Springer.

Ravindranath, N. H., Rao, S., Sharma, N., Nair, M., Gopalakrishnan, R., Rao, A. S., Malaviya, S., Tiwari, R., Sagadevan, A., Munsi, M., Krishna, N., & Bala, G.

(2011). Climate change vulnerability profiles for North East India. *Current Science, 101*(3), 384–394.

RBI, (2019). Reserve Bank of India-Publications. Retrieved November 30, 2021, from https://rbi.org.in/Scripts/Publications.aspx

Rühlemann, A., & Jordan, J. C. (2021). Risk perception and culture: Implications for vulnerability and adaptation to climate change. *Disasters*, *45*(2), 424–452. https://doi.org/10.1111/disa.12429

Saldana, J. (2011). *Fundamentals of qualitative research*. Oxford University Press.

Sati, V. P., & Vangchhia, L. (2018). Changing agriculture and cropping pattern in Mizoram, Northeast India. In Proceedings of a conference on Climate Change: Impact, Adaptation & Response in the Eastern Himalayas (pp. 17–27)

Segnon, A. C., Totin, E., Zougmoré, R. B., Lokossou, J. C., Thompson-Hall, M., Ofori, B. O., Achigan-Dako, E. G., & Gordon, C. (2021). Differential household vulnerability to climatic and non-climatic stressors in semi-arid areas of Mali, West Africa. *Climate and Development, 13*(8), 697–712. https://doi.org/10.1080/17565529.2020.1855097

Shah, K. U., Dulal, H. B., & Awojobi, M. T. (2020). Food security and livelihood vulnerability to climate change in Trinidad and Tobago. In J. Connell & K. Lowitt (Eds.), *Food security in small island states.* Springer.

Shah, K. U., Dulal, H. B., Johnson, C., & Baptiste, A. (2013). Understanding livelihood vulnerability to climate change: Applying the livelihood vulnerability index in Trinidad and Tobago. *Geoforum, 47*, 125–137. https://doi.org/10.1016/j.geoforum.2013.04.004

Shahzad, L., Shah, M., Saleem, M., Mansoor, A., Sharif, F., Tahir, A., Hayyat, U., Farhan, M., & Ghafoor, G. (2021). Livelihood vulnerability index: A pragmatic assessment of climatic changes in flood affected community of Jhok Reserve Forest, Punjab, Pakistan. *Environmental Earth Sciences, 80*(7), 1–16. https://doi.org/10.1007/s12665-021-09562-1

Sheth, C. (2020). Natural hazard risks in Dibang valley district, Arunachal Pradesh. Retrieved December 1, 2021, from https://www.conservationindia.org/wp-content/files_mf/Sheth-2020-Dibang-Natural-Hazards-full-report.pdf

Singha, P., Das, P., Talukdar, S., & Pal, S. (2020). Modeling livelihood vulnerability in erosion and flooding induced river island in Ganges riparian corridor, India. *Ecological Indicators, 119*, 106825. https://doi.org/10.1016/j.ecolind.2020.106825

United Nations. (2012). Fourth World Water Development Report. Retrieved November 30, 2021, from http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/wwdr4-2012/ (March 2013)

Upadhyayula, S. M., Mutheneni, S. R., Chenna, S., Parasaram, V., & Kadiri, M. R. (2015). Climate drivers on malaria transmission in Arunachal Pradesh, India. *PLoS ONE, 10*(3), e0119514. https://doi.org/10.1371/journal.pone.0119514

Venus, T. E., Bilgram, S., Sauer, J., & Khatri-Chettri, A. (2022). Livelihood vulnerability and climate change: A comparative analysis of smallholders in the Indo-Gangetic plains. *Environment, Development and Sustainability, 24*(2), 1981–2009. https://doi.org/10.1007/s10668-021-01516-8

Woetzel, J., Pinner, D., Samandari, H., Engel, H., Krishnan, M., Boland, B., & Powis, C. (2020). *Climate risk and response: Physical hazards and socioeconomic impacts* (p. 22). McKinsey Global Institute.